

# Researchers discover directional and long-lived nanolight in a 2-D material

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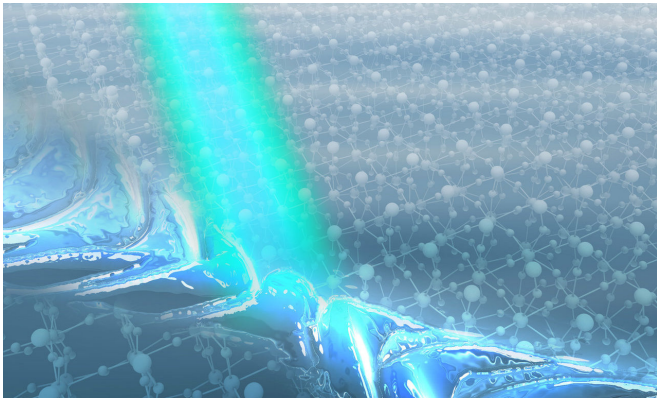


Illustration of directional nanolight propagating along a thin layer of molybdenum trioxide. Credit: Shaojuan Li

An international research team reports that light confined in the nanoscale propagates only in specific directions along thin slabs of molybdenum trioxide, a natural anisotropic 2-D material. Besides its unique directional character, this nanolight propagates for an exceptionally long time, and thus has possible applications in signal processing, sensing and heat management at the nanoscale.

Future information and communication technologies will rely on the manipulation of not only electrons but also of [light](#) at the nanometer scale. Confining light to such a small area has been a major goal in nanophotonics for many years. A successful strategy is the use of polaritons, which are electromagnetic waves resulting from the coupling of light and matter. Particularly strong light squeezing can be achieved with polaritons at infrared frequencies in 2-D [materials](#), such as graphene and hexagonal boron nitride. Researchers have achieved extraordinary polaritonic properties such as electrical tuning of graphene polaritons with these materials, but the polaritons have always been found to propagate along all directions of the material surface, thereby

losing energy quickly, which limits their application potential.

Recently, researchers predicted that polaritons can propagate anisotropically along the surfaces of 2-D materials in which the electronic or structural properties are different along different directions. In this case, the velocity and wavelength of the polaritons strongly depend on the direction in which they propagate. This property can lead to highly directional polariton propagation in the form of nanoscale confined rays, which could find future applications in the fields of sensing, heat management and quantum computing.

Now, an international team led by Qiaoliang Bao (Monash Engineering, Melbourne, Australia), Pablo Alonso-González (University of Oviedo, Spain) and Rainer Hillenbrand (CIC nanoGUNE, San Sebastián, Spain) have discovered ultra-confined infrared polaritons that propagate only in specific directions along thin slabs of the natural 2-D material molybdenum trioxide ( $\gamma\text{-MoO}_3$ ).

"We found  $\gamma\text{-MoO}_3$  to be a unique platform for infrared nanophotonics," says Qiaoliang Bao.

"It was amazing to discover polaritons on our  $\gamma\text{-MoO}_3$  thin flakes traveling only along certain directions," says Weiliang Ma, postgraduate-student and co-first-author.

"Until now, the directional propagation of polaritons has been observed experimentally only in artificially structured materials, where the ultimate polariton confinement is much more difficult to achieve than in natural materials," adds co-first author Shaojuan Li.

Apart from directional propagation, the study also revealed that the polaritons on  $\gamma\text{-MoO}_3$  can have an extraordinarily long lifetime. "Light seems to take a nanoscale highway on  $\gamma\text{-MoO}_3$ ; it travels along certain directions with almost no obstacles," says

Pablo Alonso-González, co-first author of the paper. He adds, "Our measurements show that polaritons on  $\alpha$ -MoO<sub>3</sub> live up to 20 picoseconds, which is 40 times larger than the best-possible [polariton](#) lifetime in high-quality graphene at room temperature."

Because the wavelength of the polaritons is much smaller than that of light, the researchers had to use a special microscope, a so-called near-field optical microscope, to image them. "The establishment of this technique coincided perfectly with the emergence of novel van der Waals materials, enabling the imaging of a variety of unique and even unexpected polaritons during the past years," adds Rainer Hillenbrand.

For a better understanding of the experimental results, the researchers developed a theory that allowed them to extract the relation between the momentum of polaritons in  $\alpha$ -MoO<sub>3</sub> with their energy. "We have realized that light squeezed in  $\alpha$ -MoO<sub>3</sub> can become 'hyperbolic,' making the energy and wave fronts propagate in different directions along the surface, which can lead to interesting exotic effects in optics such as negative refraction or superlensing," says Alexey Nikitinof Donostia International Physics Center (DIPC), who developed the theory in collaboration with Javier Taboada-Gutiérrez and Javier Martín-Sánchez and postdoctoral researchers at Alonso-Gonzalez's group.

The current work is just the beginning of a series of studies focused on directional control and manipulation of light with the help of ultra-low-loss [polaritons](#) at the nanoscale, which could benefit the development of more efficient nanophotonic devices for optical sensing and signal processing or [heat management](#).

**More information:** Weiliang Ma et al, In-plane anisotropic and ultra-low-loss polaritons in a natural van der Waals crystal, *Nature* (2018). [DOI: 10.1038/s41586-018-0618-9](#)

Provided by Elhuyar Fundazioa

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